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ENGINEERING SUPPORT PROGRAM

EVALUATION OF PUL-E-KHUMRI I & PUL-E-KHUMRI II MINI-HYDROELECTRIC POWER PLANTS CITY OF PUL-E-KHUMRI, NORTHERN AFGHANISTAN

MAY 2, 2010

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TETRA TECH

May 2, 2010

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Re: TETRA TECH FINAL REPORT
EVALUATION OF PUL-E-KHUMRI I & PUL-E-KHUMRI II
MINI-HYDROELECTRIC POWER PLANTS,
CITY OF PUL-E-KHUMRI, NORTHERN AFGHANISTAN

Anthony:

The Tetra Tech final report "Evaluation of Pul-e-Khumri I & Pul-e-Khumri II Mini-Hydroelectric Power Plants, City of Pul-e-Khumri, Northern Afghanistan" is submitted herein for USAID review and perusal. If you should have any questions, please contact me by phone at [redacted]

Respectfully submitted,

[redacted]
Water Resource Lead
USAID Contractor

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AFGHANISTAN ENGINEERING SUPPORT PROGRAM

EVALUATION OF PUL-E-KHUMRI I & PUL-E-KHUMRI II MINI-HYDROELECTRIC POWER PLANTS
CITY OF PUL-E-KHUMRI, NORTHERN AFGHANISTAN

May 2, 2010

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Appendix

Selected Tetra Tech Project Inspection Photographs

1.0 Introduction

1.1 General

In March 2010, Tetra Tech was requested by the United States Agency for International Development (USAID) to perform an evaluation of the United States Army Corps of Engineers (USACE) Mini-Hydropower Technical Assessment Team (TAT) Technical Assessment Reports previously completed for both the Afghanistan Mini-Hydropower Pul-e-Khumri I Power Plant and the Pul-e-Khumri II Power Plant (located in Pul-e-Khumri, Afghanistan) in March and April of 2008. A Tetra Tech team travelled to Pul-e-Khumri on 10 April 2010 to visit with the plant staff to gain additional information on the two facilities as well as take note of improvements having been made as a result of the USACE inspection team's findings and recommendations made in April 2008. Tetra Tech finished its work at the two sites on 12 April 2010.

USAID previously engaged the services of the USACE Afghanistan Engineering District (AED) and the Corps Hydroelectric Design Center (HDC) to investigate and evaluate the conditions at these two mini-hydroelectric power generating sites and provide its site assessments in March and April of 2008. The purpose of that work was in support of the overall USAID program to restore and/or otherwise further develop Afghanistan's in-country hydroelectric resources. During the TAT inspections, no testing was performed other than certain demonstrations of equipment operation.

1.2 Purpose of Tetra Tech Report

The primary purpose of this Tetra Tech report is to present an update to the two inspection reports prepared by the USACE in April 2008 for two existing mini-hydroelectric power plants located at the City of Pul-e-Khumri in the Baghlan Province in northern Afghanistan. These power plant sites include the Pul-e-Khumri I and Pul-e-Khumri II mini-hydroelectric dams and power plant facilities.

Tetra Tech project staff and GardaWorld security staff traveled to the City of Pul-e-Khumri on 10 April 2010 and spent two days visiting the plant staff at the Pul-e-Khumri I hydroelectric plant facility and one day at the Pul-e-Khumri II hydroelectric plant facility. Tetra Tech personnel stayed at the Baghlan Hungarian PRT[redacted]nd (USAID Field Program Officer at the Baghlan Hungarian PRT) assisted Tetra Tech in setting up meetings with the appropriate hydroelectric plant staff as well as provided needed information on the two sites. Several Pul-e-Khumri plant managers and senior engineering staff met with Tetra Tech project personnel (see listings below). A GardaWorld security staff member served as the language interpreter.

<u>Attendees at Pul-e-Khumri I Plant:</u>

Plant Engineer [redacted]	Director for Seasonal Power Point [redacted])
Plant Engineer [redacted]	Director of Engineering ([redacted])
Plant Engineer [redacted]	Main Director
Plant Engineer [redacted]	Deputy Engineer
[redacted]	Tetra Tech
	Tetra Tech
	GardaWorld Translator

Attendees at Pul-e-Khumri II Plant:
Plant Manager [redacted] Acting Chief Director
Plant Engineer [redacted] Electrical Lab Director
Plant Engineer [redacted] Engineer
[redacted] Tetra Tech
Tetra Tech
GardaWorld Translator

The purpose of each plant site visit was to review plant work that may have been performed in the interim concerning the USACE recommendations given to the plant operators two years ago, update any related information, identify plant improvements, and to perform a limited reconnaissance task, take project photographs, and to report on anything new for the two facilities.

The USACE reports are titled the Afghanistan Mini-Hydropower Pul-e-Khumri I Technical Assessment Report and the Afghanistan Mini-Hydropower Pul-e-Khumri II Technical Assessment Report. Both reports are dated April 28, 2008 and were prepared by the USACE Mini-Hydropower Assessment Team. Sponsorship was provided by USAID. The USACE presented in detail the observations, findings and specific details of each hydro plant facility after conducting separate inspections at the two facilities in April 2008, two years before the time of the Tetra Tech site visits. Photographs taken by Tetra Tech personnel that depict and support certain aspects of the Tetra Tech commentary that follows herein are presented in the Appendix.

1.3 Power Plant Project Location(s)

The City of Pul-e-Khumri, with a USACE-reported population of 191,600 (circa 2008), is located in the northern part of the Baghlan Province approximately 225 kilometers (km) north of Kabul, Afghanistan on the A76 Highway (see Figure1). Name variants for the city include Pul-e-Khumri, Pul-e Khomri, Pol-e Khomri, Poli Khomri, and Pul-i-Khomri.

The two hydroelectric powerhouses are located in the city on an irrigation canal that runs generally parallel to the Baghlan River. The locations of the Pul-e-Khumri I and II hydroelectric dams and power plant facilities are indicated on Figure 1. The Pul-e-Khumri I dam and power house is located to the south and upstream of the Pul-e-Khumri II dam at a distance of approximately six kilometers (6 km). The Baghlan River flows in a generally south to north direction through the City of Pul-e-Khumri. The power plant latitude and longitude coordinates and approximate site elevation data are noted below.

N Pul-e-Khumri I Power Plant Coordinates (upstream plant site)
MGRS: 42S VE 73983 77476
Latitude: N 35.94122 degrees
Longitude: E 68.71156 degrees
Approx. Site Elevation: 638 meters (638 m)

N Pul-e-Khumri II Power Plant Coordinates (downstream plant site)
MGRS: 42S VE 71884 81991
Latitude: N 35.98194 degrees
Longitude: E 68.68811 degrees
Approx. Site Elevation: 618 meters (618 m)

1.4 Hydroelectric Power Plant Histories

The Pul-e-Khumri I dam and powerhouse, located upstream of the Pul-e-Khumri II hydroelectric facility, was built in 1941 using German equipment. This plant belongs to the Ministry of Mines and Industry and reportedly is operating at low capacity. The powerhouse has an installed capacity of three 1.6 MW Kaplan-type turbine units (4.8 MW total). Each turbine unit has generators rated at 2.0 MVA, or 1.6 MW each, and the plant has a total nameplate generation capacity of 6.0 MVA, or 4.8 MW.

The Pul-e-Khumri II power house was built on the Baghlan River in 1964 by the United Soviet Socialist Republic (USSR). The original three Russian Kaplan turbines are in place and operational. However, this three-unit 9.0 MW plant (which also belongs to the Ministry of Mines and Industry) is operating at a low capacity (3.6 MW) due to governor and voltage regulator problems and limited by the existing much reduced capacity due to excess sediment loading in the power canal over a reported period of 30 years without having been dredged. The purpose of this plant was to provide power to the towns of Pul-e-Khumri, Baghlan, and Kunduz. Typically, only one turbine unit is operated (at approximately 750 kW) during the winter periods due to low river flow conditions.

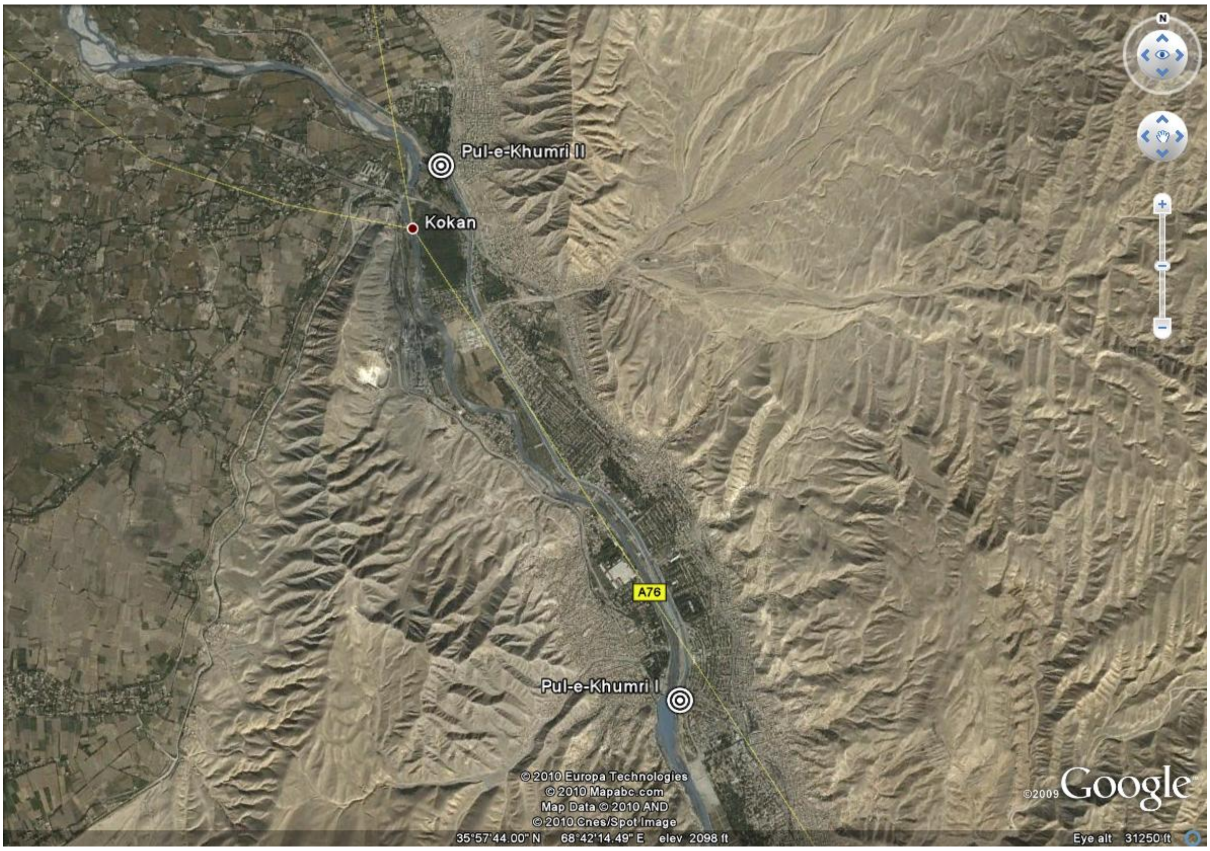


FIGURE 1 – PUL-E-KHUMRI I AND II HYDRO PLANTS LOCATION MAP

2.0 Average Project Life of Hydroelectric Power Plant Facilities

For general reader information purposes, the average project life for several hydroelectric power plant components at a typical hydroelectric power plant facility, including structural, mechanical and electrical components are provided below.

Type of Structure/Facility	**Average (Expected) Project Life**
1. Concrete Dams	100 to 150 years
2. Waterways	
a) Penstocks	
i) Steel	40 to 50 years
ii) Concrete	25 to 50 years
b) Canals and Tunnels	50 to 100 years
3. Power House and Equipment	
i) Buildings	35 to 50 years
ii) Generators	25 years
iii) Transformers	30 years
iv) Turbines (hydraulic)	5 years
v) Pumps	20 to 25 years

3.0 Generalized Preventive Maintenance and Inspection Schedule for Hydroelectric Power Plant Facilities

For reader information purposes, a generalized preventive maintenance and inspection schedule is presented below for hydroelectric power plant facilities.

Inspection/Maintenance Frequency	**Hydroelectric Power Plant Facility Component Parts**
Monthly	i) Turbine cover parts (check for leakage, drainage holes, servomoter connections, turbine shaft and cover, oil pump, etc.) ii) Operating rings of turbines iii) Guide vane mechanisms
Quarterly	i) Servomotors ii) Ejector cabinet feedback systems
Bi-annually (twice per year)	i) Governor mechanisms ii) Gauges iii) Grease pumps for guide vanes and guide bearings iv) Grease pipes connected to grease pumps
Annually	i) Turbine auxiliaries (i.e., oil pressure tanks, turbine guide bearings, turbine instrumentation) ii) Scroll casing runners with guide vanes iii) Emergency slide valves iv) Pit liners v) Draft tubes vi) Runner blades (check for cavitational damages, cracks, and overall wear)

4.0 Pul-e-Khumri I Power Plant Facility

In the USACE April 2008 report, several recommendations were made relative to the mechanical, electrical and civil works components of the Pul-e-Khumri I facility that included both short- and long-term recommendations, and are addressed in the following paragraphs. Tetra Tech is in overall general agreement with the USACE Pul-e-Khumri I findings in April 2008.

4.1 USACE-Reported Mechanical Equipment Conditions and Recommendations

Most of the mechanical equipment at the existing Pul-e-Khumri I mini-hydroelectric power plant facility reportedly is original, except for the turbines which were replaced (circa 1970) because of extensive erosion and cavitation damage to the turbine runner blades. However, the existing turbines previously installed reportedly had been "used" equipment from another plant and were not specifically designed for this plant facility. The runner blades of the existing turbines also have undergone considerable erosion and cavitation damage.

In the USACE April 2008 report, short-term recommendations were made relative to the mechanical components of the Pul-e-Khumri I facility that included the replacement and/or rebuilding of the governors and the installation of new turbine runners, couplings and guide bearings. The USACE short-term electrical recommendations were made to repair the governor system and voltage regulators, repair the main unit breakers, feeders, disconnects and miscellaneous electrical equipment, and perform miscellaneous diagnostic testing of the generators and transformers. Other short-term recommendations included ordering/procuring spare parts, dredging the existing power channel, and replacing a leaking roof to the existing power house. The USACE further recommended that the repair and replacement work be contracted separately, however, that plant staff could be used for the labor forces.

At the time of the USACE site visit to this facility two years ago, two Kaplan turbine units, designated U2 and U3 were operating with a total output of 1.4 MW (the reported maximum output then). The first Kaplan turbine unit, designated as U1, reportedly was not in use because of a failed governor step motor. A plant staff member at that time indicated that during low river flow conditions, particularly in late summer, only one unit could operate and then only for a few weeks. This situation was also reported to Tetra Tech during the recent visit. The plant superintendent previously estimated that the repair of certain components (i.e., governors, breakers, and exciters) in addition to increasing the hydraulic capacity of the downstream power canal to the Pul-e-Khumri II dam and powerhouse facility would allow an increase in plant power output by 2.24 MW for a total output capacity of at least 3.84 MW (USACE, April 2008).

Two years ago, the U1 Kaplan turbine unit was also disassembled for making turbine modifications (welding the Kaplan runner blades in fixed position and repairing the wicket gates). These repairs were needed because of inadequate pressure in the governor hydraulic system. (Similar repairs had already been made to the U2 and U3 Kaplan turbine units, however, welded Kaplan turbine blades reduce unit efficiency and reduce the ability to match generation to the grid load.) The USACE, therefore, recommended that new turbine runners, couplings, and guide bearings be installed including the replacement and/or rebuilding of the governors to increase plant power output capacity by 4500 kW to 8100 kW and to at least a reported restored plant rated capacity of ninety percent.

4.2 USACE-Reported Electrical Equipment Conditions and Recommendations

4.2.1 Electrical Equipment Conditions

The Pul-e-Khumri I power plant reportedly has most of its original installed electrical equipment, and there have been very few modifications made to the existing equipment. The USACE reported the overall condition of the electrical equipment to be in a fair condition and mostly functional. General maintenance and housekeeping activities, however, were reported as not being totally satisfactory and needing improvement, as all the generator stators, rotors, and exciters showed signs of poor housekeeping, and the breakers for each turbine unit and distribution were noted to be in poor condition and needed replacement. Additionally, the USACE took note of several electrical cables that showed signs of insulation deterioration because of a lack of proper maintenance and that replacement was necessary to prevent faults and provide protection against potential shock hazards, as well as, upgrading the relays and fuses (to be replaced with the breakers) in the switchgear. Because no spare parts are readily available to date (as of 12 April 2010), the electrical components will continue to be subject to unnecessary wear.

In April 2008, the plant staff also indicated that they were having problems with the step motors on the regulators, and that the generators were beginning to fail and could not be repaired because of spare parts not being readily available.

4.2.2 USACE-Reported Electrical Recommendations

For the Pul-e-Khumri I power plant electrical components, the USACE reported that the electrical equipment was in good condition overall, however, certain repairs and the replacement of certain items and equipment would be necessary. To reiterate, the USACE recommended the following action items to the plant staff in April 2008, for both short-term (i.e. immediate) action and long-term action.

USACE short-term electrical recommendations for immediate action (excerpted from April 2008 report) with notes by Tetra Tech are listed below.

1) Clean all generator stators, rotors, and exciters. <u>(Note: The plant staff reported to Tetra Tech on 10 April 2010 that this work was already ongoing.)</u>
2) Megger U1, U2, and U3 stator windings and rotor field windings.
3) Replace wiring from the regulator to the exciter for all units.
4) Repair all generator voltage regulators.
5) Inspect all switchgear wiring to ensure proper connection from equipment.
6) Replacement control relays and fuses are needed for the switchgear (List of items needed for project).
7) Replace all feeder breakers, main unit breakers, and disconnects.
8) Install new protective relays for each breaker.
9) Inspect, clean, and megger all transformers for proper operation and condition.
10) Test transformer oil.
11) Replace deteriorated and damaged cable in cable gallery/room.
12) Provide spare parts list for equipment (List of items needed for project).

USACE proposed long-term action items (excerpted from April 2008 report) are listed below.

1) Replace all fuse panels with circuit breaker panels.
2) Perform proper maintenance on all rotors, stators, and excitation systems. This will include maintenance of commutator surfaces, slip ring surfaces, new brushes, and the replacement of any faulty wiring.
3) Develop plan for rehabilitation of all power plant electrical systems and equipment.

4.3 USACE/Tetra Tech-Reported Civil Works Observations and Recommendations

The USACE-proposed short-term (i.e., immediate) action-item recommendations made in April 2008 included the following work items, which are excerpted and noted in bold print. As a result of the Tetra Tech site visit and inspections on 10 April 2010 and 12 April 2010, additional Tetra Tech commentary is presented in the non-bold type herein.

4.3.1 Immediate Action Recommendations

1) Procure 12-mm diameter wire rope for recabling the existing trash rack using available plant labor forces (mandatory). During the USACE inspection, the trash rake was demonstrated and operated properly. However, the trash rake operator noted that a 12-mm cable that operates the rake teeth had failed in the past and had been replaced by a 10-mm cable because that's what they had available. The rest of the 12-mm cable on the trash rake was noted as showing wear as well.

During Tetra Tech's two site visits to this facility, the trash racks and trash rake were noted as being operational and functional. The second site visit was made soon after heavy rainfall and minor flooding on the Baghlan River had occurred and it was observed that the equipment was capable of removing a significant amount of debris. To date however, the recabling repair requirement noted in the USACE report has not been performed.

2) Make Spillway repairs: The following repairs are sequenced to expedite the repair process from upstream to downstream and to conduct as much of the work "in the dry" as possible.

To Tetra Tech, the spillway gates and seals appeared to be in the same condition as observed during the previous USACE inspection. Again, an examination of gate opening procedures was not conducted due to time constraints and present plant operations.

The recommended preferred time period for this work would be during the normal low-flow season on the Baghlan River, which should be during the months of June through October. Also, in order to perform the spillway repairs, cofferdams will need to be constructed above and below each spillway and stilling basin structure (includes stilling basin blocks) in order to perform ready repairs as needed. Dewatering of the spillway structure foundation within each cofferdam enclosure will also be required to the best extent practical. Spillway repairs should be conducted at a single spillway structure, one at a time. (Also, each cofferdam structure(s) will need to be designed accordingly.)

a. Spillway Closure Bulkheads/Wheels. Inspect the bulkhead seals and wheels (mandatory) and repair or replace the seals and wheels.

The spillway closure bulkheads appeared to be in the same condition to Tetra Tech personnel as observed during the USACE inspection, however, Tetra Tech was unable to actually examine the roughness condition that was reported by the USACE. Also, the intake gates remain functional. As previously noted by the USACE, the gates are all operated manually and require significant efforts to open. Furthermore, the plant staff indicated the lifting mechanism has not been oiled. This absence of lubrication maintenance only serves to increase the efforts required to lift these gates.

b. Spillway gate operability and seals. Inspect the gate operability and seals (mandatory) and repair or replace any gate wheels and gate seals (with PVC seals if appropriate).

As previously noted by the USACE, the turbine intake gates are all operated manually and require significant efforts to open. During the Tetra Tech site visit and inspection, it was observed that the turbine intake gates remain functional, however, the running gears for the gates and other accessories still have not been well lubricated/greased, and appeared dry. This lack of maintenance adversely affects the overall ease of gear operation and lifting these gates.

c. Spillway Apron. Fill the holes at the leading edge of the spillway aprons, bays 1– with concrete (mandatory).

The severe erosion of the ogee spillway crest, chute and apron was also observed during the Tetra Tech site visit. However, this erosion could only be observed from a distance so its full extent is unknown, but it appears severe. The USACE previously reported that the damage was such that it threatens to undermine the spillway structure itself causing catastrophic collapse. A structural evaluation needs to be performed for the ogee spillway, chute and apron structures in each bay and remediation repairs performed as soon as possible. The structural evaluations need to include the spillway wall sections below the ogee crests. The lower sections of these walls should also be filled/fixed with concrete as well as with additional steel plate sheeting anchor-bolted to the walls to provide future protection against the adverse erosive effects of hydraulic jump conditions against the concrete, in addition to, the negative effects of freeze and thaw icing conditions during the winter period. (The negative pressure distributions that can occur within a given hydraulic jump situation have significant erosive potential against concrete.)

3) Repair Power House roof (mandatory).

The power house roof leakage problem reported in the USACE April 2008 report reportedly has been temporarily fixed. Plant staff indicated that the leak areas had been patched using an asphalt roofing material. However, this roofing fix should be considered as being temporary only and complete replacement of the roof section may be necessary.

4.3.2 USACE Proposed Long-term Recommendations (excerpted from April 2008 report)

1) Spillway Ogee and Apron. Conduct a complete survey of the spillway ogee and run out (mandatory). Repair the damaged areas (optional, based on severity and cost estimate).

See above discussion on immediate repairs.

2) Right entrance wing wall. Seal the crack with an elastomeric sealant. The plant staff should monitor for future leakage, especially after a seismic event.

Water at the right-side wing wall (looking downstream) at the entrance to the U1 turbine unit was previously observed by the USACE to seep through a horizontal joint. During the winter period, the seepage reportedly increases. No damage was reported by the USACE, however, it was recommended that the horizontal joint could be sealed using an elastomeric sealant.

The crack leakage along the right apron wing wall as reported in the USACE April 2008 report was not observed during the Tetra Tech site visit. However, this may have been because of higher water levels at the time of the Tetra Tech visit.

3) Left downstream training wall. The repair of this wall is not essential to power production. Complete a full survey of the damaged area, including foundation characterization (mandatory). Design and construct a repair (mandatory).

As indicated in the USACE April 2008 report, the left-bank downstream training wall is in a state of disrepair and collapse. The plant staff indicated that they no longer use Spill Gate 4 and this action subsequently reduces the potential for river flows to continue eroding the bank side. It appeared as if the spill gate had not been used for some time as there was significantly less wear here than at the other three spill gates. The plant staff also indicated that flow was typically not enough to justify all four spill gates being used. Assessing the full extent of needed repairs will require additional site-specific analysis including surveying, a local geotechnical investigation, and structural engineering designs for constructing river bank protection improvements.

Tetra Tech personnel were not allowed to get close to the wall section described above because of security reasons. At a minimum, a limited geotechnical investigation and ground survey would be required to prepare a remediation design for stabilizing the existing foundation condition and preparing a suitable subgrade foundation for a new reinforced concrete continuous floodwall structure to replace the damaged wall sections. Along the right-bank side too, and in like fashion, new reinforced concrete wall sections are recommended to be designed and constructed for effectively channeling river flows at this side of the river to protect against future erosion as well.

Also, it appears that at one time several concrete stilling basin blocks that had previously been located (situated) immediately downstream of the spill gates and stilling basin apron areas had been completely or partially destroyed and the concrete segments removed downstream, probably during a major flooding event(s) on the Baghlan River. (No stilling basin blocks, however, were observed as existing below Spill Gate 3. Reconstructing and/or rebuilding the stilling basin blocks in their former locations, particularly at the Spill Gate 4 location, would serve to dissipate the energy from the gate flows, and in particular, reduce the potential of erodible flood-prone river flows, including eddy currents, at the left-bank side of the river thus reducing the chances for further damage to the left bank-side training walls and supporting foundations.

4) Draft tube deck at +14.75. Stiffen the deck as necessary (optional).

There were no additional matters observed concerning the draft tube deck beyond that reported by the USACE in its April 2008 report, namely the corroded steel substructure, corroded steel reinforcement, and exposed steel reinforcement.

4.3.3 USACE Standard System-Wide Recommendations (excerpted from April 2008 report)

1) Establish and fund routine maintenance program for each project.

Tetra Tech concurs.

2) Identify and establish an inventory of spare parts, equipment, and emergency materials.

The average project life of the individual hydroelectric power plant components presented in Section 2 can be used as a guide for plant personnel in procuring and maintaining a suitable inventory of the important spare equipment and parts. At the time of the Tetra Tech visit, nothing had been accomplished in the way of ordering spare parts since the USACE April 2008 inspection.

3) Perform a system-wide evaluation of hydrologic conditions and subsequent system management program.

The Pul-e-Khumri I plant personnel could not produce hydrologic records (river flow or flow-duration data for the Baghlan River nor flow information for the power canal. Rather only records of the power generated (in Megawatts) by the hydro plant operations (an example data record sheet is shown on Figure 2). There is a staff gage located on one wall structure, however, apparently it is not routinely used for water stage monitoring purposes.

4) Collect, duplicate, scan and archive project documents, technical data, and relevant technical information. Maintain set at each project, a set at the Ministry office, and a set in secure archives.

Tetra Tech concurs.

5) Include seismic considerations in all future design and repairs.

Tetra Tech concurs.

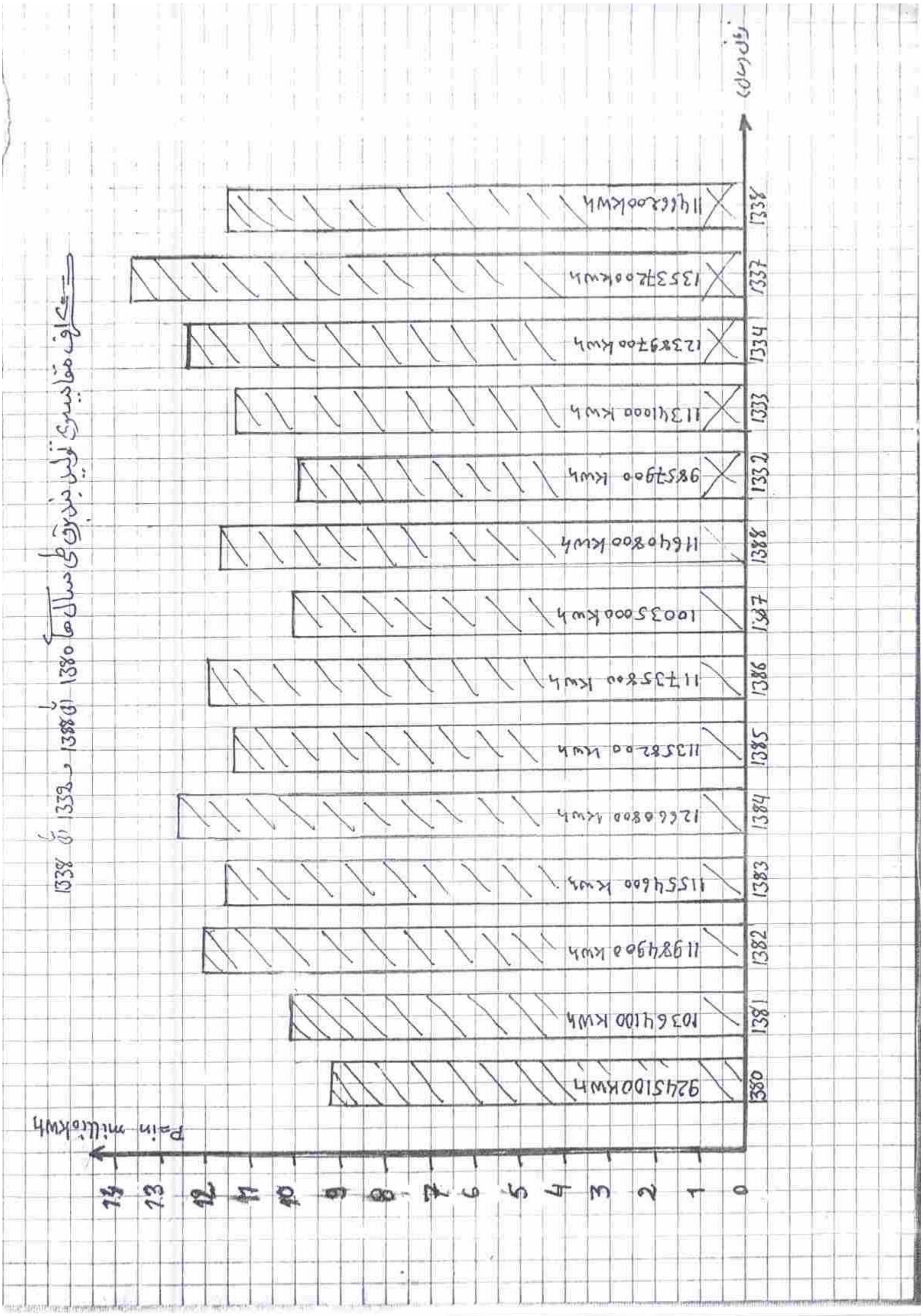


FIGURE 2 – TYPICAL PUL-E-KHUMRI I HYDRO PLANT OPERATIONS DATA RECORD SHEET (NOTED POWER GENERATION UNITS NOTED IN MEGAWATTS)

4.4 Other Tetra Tech Comments

4.4.1 Upstream Reservoir Pool Sedimentation

At the time of the Tetra Tech site visit to this facility (10 April 2010), the upstream reservoir pool sedimentation did not appear to adversely affect the operation of the dam and appurtenances. However, previous sedimentation blockage of the spill gates was apparent from the evidence of past upstream flooding. Portions (i.e., segments) of reinforced concrete walls located upstream from the dam had undermined and fallen into the Baghlan River.

On 12 April 2010 during a second site visit, in the afternoon after a storm event had occurred during the previous night and when there was slight flooding on the Baghlan River, the river was observed to have a high sediment load above the dam. In addition, there was a significant amount of debris that had collected behind the dam and had already been removed to the top of the dam. It was observed that the trash racks and trash rake proved operational and functional and the equipment was capable of removing a significant amount of debris. However, to date, the proposed repair requirements for the trash racks and trash rake noted in the USACE April 2008 report have not been performed.

4.4.2 Power Plant Bypass Channel

The Pul-e-Khumri I powerhouse has a bypass structure for the power channel that leads to the downstream Pul-e-Khumri II facility. This bypass channel appeared to be in proper operation at the time of the Tetra Tech visit.

4.4.3 Turbine Intake Gates

As previously noted by the USACE, the turbine intake gates are all operated manually and require significant efforts to open. During the Tetra Tech site visit and inspection, it was observed that the turbine intake gates remain functional, however, the running gears for the gates and other accessories still have not been well lubricated/greased, and appeared dry, thus this lack of maintenance adversely affects an overall ease of gear operation and lifting these gates.

4.4.4 Downstream Controls to Power Canal and River

The downstream controls to the power canal and Baghlan River appeared to be working as they had during the USACE site inspection visit in April 2008. The plant staff gave no indication of operational failures.

4.4.5 Downstream Canal Sedimentation

No work has been performed to date to remove the existing sediment in the power canal between the Pul-e-Khumri I and Pul-e-Khumri II hydro plant sites. While enroute to the Pul-e-Khumri I dam, Tetra Tech personnel observed that the water depth along the canal edges is extremely shallow, being close to about 1/2 meter. It was difficult to gage the water depth at the center of the canal, but it should be deeper in the main thread of flow. However, a significant dredging effort in this canal must be undertaken to remove the existing sediment along the approximately 6 km between the two plant sites if hydropower output is expected to be increased.

4.4.6 Site Foundation Conditions

Tetra Tech project personnel performed a general visual inspection of the foundation conditions at this hydroelectric facility and are in agreement with the USACE April 2008 report. There was no evidence of ground settlement, depressions, seepage, or slope failure found on site. (There was no geotechnical investigation or foundation analysis performed by Tetra Tech during this site visit.) As stated in the USACE report, rehabilitation and reconstruction will need to consider that this site is subject to potentially high levels of seismic shaking. (Note: There is a high level of seismic design uncertainty in Afghanistan, primarily due to existing partial records only of in-country historical seismic events.)

4.4.7 Safety Protection (hand railings and signage)

There is a lack of adequate safety hand railings on the existing dam, including lack of safety signage, for the protection of plant staff and/or visitors walking along the tops of the concrete structures, as above the gates and spillway structures. This lack of safety protection was not addressed at all by the USACE in its inspection reporting. Safety protection should comply with the USACE "**SAFETY AND HEALTH REQUIREMENTS MANUAL**" (EM 385-1-1, 2008 or earlier 2005 edition). Pipe handrails to at least a minimum height of 0.9 meter (0.9 m) should be installed at all locations where needed and to match up with the existing handrails.

5.0 Pul-e-Khumri II Power Plant Facility

In the USACE April 2008 report, short-term recommendations were made relative to the mechanical components of the Pul-e-Khumri II facility that included the replacement of wicket gate bushings, a turbine shaft coupling repair, the replacement and/or rebuilding of the governors, and the replacement of raw water strainers. Several short- and long-term electrical and site civil recommendations were also made by the USACE and are addressed in the following sections. Tetra Tech is in overall general agreement with the USACE Pul-e-Khumri II findings in April 2008.

5.1 USACE-Reported Mechanical Equipment Conditions and Recommendations

The USACE mechanical recommendations in April 2008 included the following as-needed items:

1) New wicket gate bushings (for three units)
2) Throat ring repair (for three units)
3) Un-welding of the turbine blades and ensuring that the runner blade servo is operational (for three units)
4) Turbine shaft coupling repair (for one unit)
5) New governor air compressor (for one unit)
6) New governor oil pumps and controls (for three units)
7) Governor rebuild kits (for three units)
8) New 4-inch twin basket or auto-flush raw water strainers (for three units)

To date, the above-noted as-needed items have not been procured by plant staff, and are still needed.

5.2 USACE-Reported Electrical Equipment Conditions and Recommendations

5.2.1 Electrical Equipment Conditions

As with the Pul-e-Khumri I power plant facility, the Pul-e-Khumri II power plant has most of its original installed electrical equipment and there have been very few modifications made to the existing equipment there as well. Again, the USACE reported the overall condition of the electrical equipment to be in a fair condition and mostly functional. However, the general maintenance and housekeeping activities were reported by the USACE to not be totally satisfactory and needing improvement, primarily so as to not subject the electrical components to unnecessary wear.

The overall condition of the electrical equipment in this facility was reported as fair by the USACE and mostly functional. Housekeeping and general maintenance, however, were not held to a high standard; this neglect reportedly had subjected the electrical components to unnecessary wear.

5.2.2 USACE-Reported Electrical Recommendations

For the Pul-e-Khumri II power plant electrical components, the USACE reported that the electrical equipment was in good condition overall, however, certain repairs and the replacement of certain items and equipment would be necessary. To reiterate, the USACE recommended the following action items to the plant staff in April 2008, for both (immediate) short-term action and long-term action.

USACE short-term electrical recommendations for immediate action (excerpted from April 2008 report) are listed below.

1) Clean all generator stators, rotors, and exciters.
2) Megger U1, U2, and U3 stator windings and rotor field windings.
3) Clean out all debris from wire/cable raceways (avoid disturbing existing cable).
4) Repair all generator voltage regulators (additional research for components is necessary).
5) Inspect all switchgear wiring to ensure proper connection from equipment.
6) Replacement control relays and fuses (use cartridge fuses if possible) are needed
7) Repair feeder breakers (#11 and #15). This will require troubleshooting the equipment. Replacement of breaker components or protective relays may be necessary. If the breaker cannot be repaired, replacement is recommended.
8) Inspect, clean, and megger all transformers for proper operation and condition.
9) Test the transformer oil.
10) Test (for proper operation) and clean all main unit circuit breakers.
11) Replace battery bank and charging system.
12) Provide spare parts for equipment (List of items needed for project).

USACE proposed long-term goals (excerpted from April 2008 report) are listed below.

1) Repair annunciation.
2) Replace all gate- and intake-indicating meters in switchgear.
3) Perform proper maintenance on all rotors, stators, and excitation systems, to include maintenance of the commutators surfaces, slip ring surfaces and new brushes, as well as to replace any faulty wiring
4) Develop a plan for the rehabilitation of all power plant electrical systems and equipment.

5.3 USACE/Tetra Tech-reported Civil Works Observations and Recommendations

The USACE-proposed short-term (i.e., immediate) action-item recommendations made in April 2008 included the following work items, which are excerpted and noted in bold print. As a result of the Tetra Tech site visit and inspections on 11 April 2010, additional Tetra Tech commentary is presented in the non-bold type herein.

5.3.1 Immediate Action Recommendations

1) Power canal. Dredge the 6 km of intake canal from the penstock intake to the tailrace at Pul-e-Khumri I (Baghlan 2), preferably and if possible should be performed "in the dry" and when the powerhouse is shut down for repairs or because of inadequate flow.

The power canal supplies the source of water to the power house of Pul-e-Khumri II and starts at the Pul-e-Khumri I tailrace (Baghlan 2) approximately 6 km upstream. The canal flows are diverted from the Baghlan River at the Pul-e-Khumri I facility. The USACE report stated that poor hydraulics in this canal was one of the major limiting factors for power generation at this site and recommended dredging the canal of the accumulated sediments for approximately the 6 km distance. The poor hydraulic condition is caused by excessive sedimentation in the canal which has occurred over the last 30 years. The plant staff has indicated that low-flow conditions in the Baghlan River significantly reduce the power-generating capacity at the dam. Given that the mechanical power produced at a turbine shaft (measured in watts) is directly proportional to the amount of flow (in m^3/sec) passing through the turbine and the effective pressure head of the water (in m) across the turbine, it is easy to realize the reduced potential in generating electrical power.

The USACE report presented the rough dimensions of the canal as being 25 m wide x 4 m deep and being approximately 6 km in length. (The 25-meter width referred to is the canal top width.) The USACE also estimated that there was a 2-m depth of sediments along the canal bottom. Observations of the power canal made by Tetra Tech corroborates the former USACE assessment. Based on the visual observations by Tetra Tech, the canal was extremely shallow along its banks, however, the center of the channel was deeper but not verifiable because it was impractical to make direct measurements at the time of the Tetra Tech site visit. The USACE previously estimated (in April 2008) that 300,000 m^3 of sediment was present in the canal, however, the sediment accumulation may be slightly greater now (i.e., on the order of 6 to 7 percent greater because of the interim 2-year period). Moreover, the projected volume of sediment to be removed should probably be increased for project bidding purposes.

Based on the dimensions shown on Figure 3 for the Ghori Breshna Water Canal Plan and the USACE reporting above, the existing carrying capacity of the existing power canal system is on the order of 39 m^3 per second, which is roughly 70 percent less than the total carrying capacity of the canal system of 144 m^3 per second without the deposited sediment.

Dredging the canal of the sediments (upwards of an estimated 300,000 cubic meters and more) is the only solution to achieve the former total carrying capacity of the canal needed for restoring the original power generating capacity of the existing dam facility. A selected dump site for the dredged sediments from the canal is reported to be located in the Kar Kar area (the grid for the general dump area is 42SVE7684) and is located approximately 20 to 25 km away from the City of Pul-e-Khumri.

Also, as noted in the USACE report, unexploded ordnance (UXO) presents a real safety hazard for performing dredging activities in the power canal. Therefore, safety procedures for detecting and disposing with UXOs must be developed in advance of any future dredging work to be performed in the power canal.

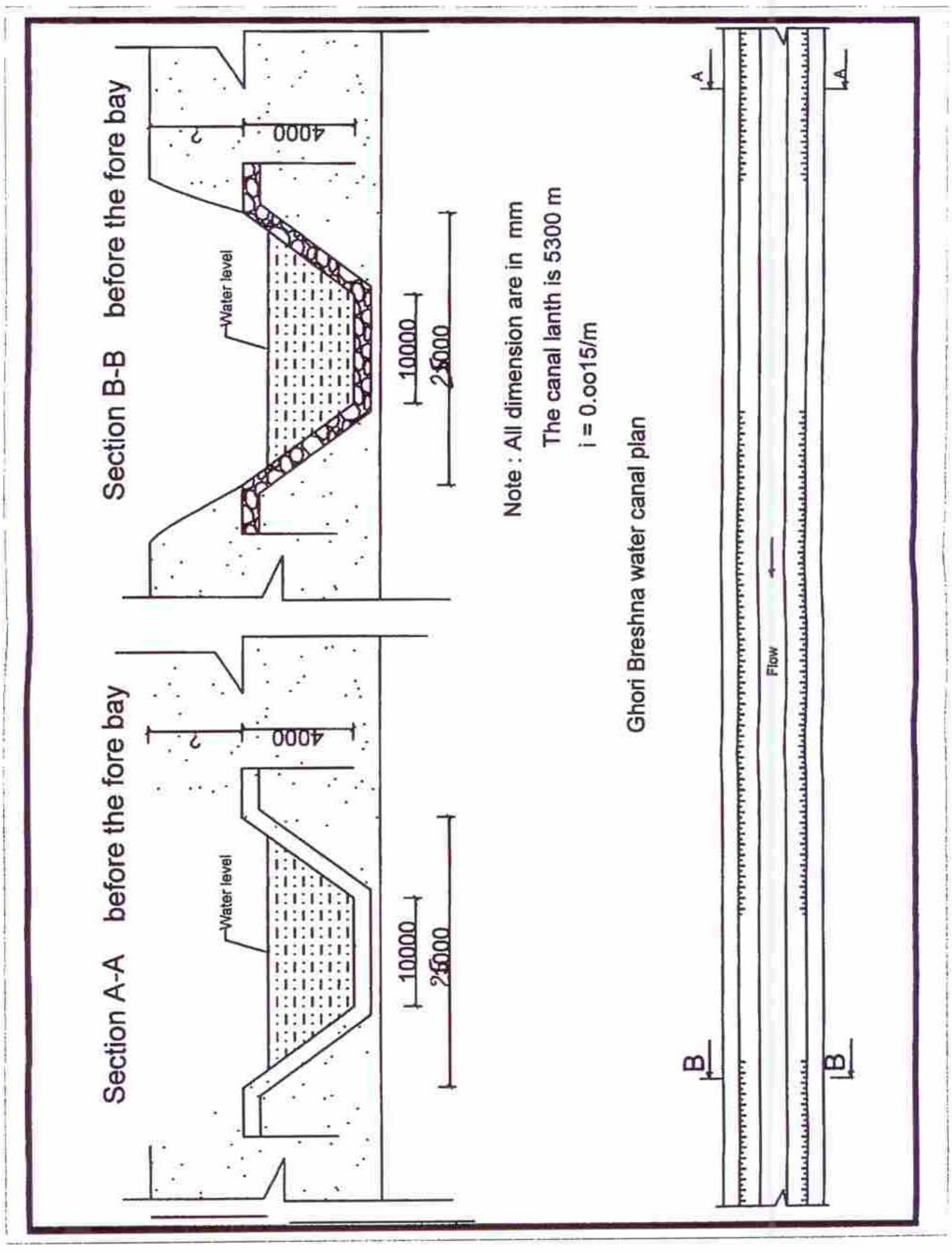


FIGURE 3 – TYPICAL GHORI BRESHNA WATER CANAL PLAN

2) Sluice gate operator. Investigate the failure mode of the operator (mandatory) and either repair or replace.

The sluice gates are used to control the flows and distribution of water to the Kaplan turbines. Each intake sluice gate is also used for sluicing sediment below the entrance of the intake to downstream. Three sluice gate operators are located on the intake deck to the right side of the intake structure building (looking downstream). At the time of the USACE inspection, two of the sluice gates were noted as being operational, but one was down. Although disassembled, the plant staff at the time did not know what was wrong with the sluice gate operator, nor was there a name plate to identify that equipment.

The operation of the sluice gates was not examined during the Tetra Tech site visit, except to take note that the gear mechanisms for the gate hoists had not been properly lubricated. The lack of lubrication matter was discussed in the commentary for the Pul-e-Khumri I hydropower plant facility.

3) Penstock closure bulkhead, wire rope. Confirm the size, length and type and procure wire rope for the #1 penstock closure bulkhead (mandatory). Install or use project labor to install.

The penstock closure bulkheads located within the intake structure building are in good condition. However, the 24-mm diameter (or 25-mm diameter) wire rope used to hang Bulkhead #1 had previously been "cannibalized" for use on Bulkhead #3. The overall length of wire rope includes numerous windings on a drum, and routing of the cable overhead and down to each end of the bulkhead to ensure a uniform lift. The USACE had estimated a total length of wire rope to be approximately 150 m.

The penstock closure bulkheads were not examined during this Tetra Tech site visit and there are no comments beyond the USACE inspection findings. However, the plant staff indicated that there had been no repairs made to the penstock closure Bulkhead #1 since the USACE April 2008 inspection.

4) Downstream Gates and Bulkheads

The operation of the downstream gates was not demonstrated, however, a visual examination of the gates and bulkheads by Tetra Tech revealed no excessive deterioration since the time of the USACE inspection and reporting on the same. Also, the plant staff did not indicate problems with this equipment and indicated that all downstream gates and bulkhead equipment were operating properly.

5.3.2 USACE Proposed Long-term Recommendations (excerpted from April 2008 report)

1) Power house structure, crack in end wall. Mark, measure, date and regularly monitor at several locations across the crack to determine if the crack is still active. If active, long term repair is dependent on the mechanism and the structural framing.

The USACE report identified a large crack running generally vertically adjacent to and just inside and between the main entrance and the column corner of the existing power house structure. Procedures for monitoring the crack activity were proposed by the USACE at its time of inspection. However, the plant staff did not indicate they had been tracking any crack growth or further generation as recommended by the USACE in April 2008. Comparing photographs from those presented in the USACE report with those taken during the Tetra Tech site visit, it does not appear as if the crack has enlarged in the interim. As this crack runs along one of two walls in this direction, it is likely that this is acting as a shear wall, in which case it is needed to absorb horizontal loads. These loads are of particular concern in Afghanistan where there is a high probability of earthquakes. Additional cracks are scattered at various locations on the power house walls. Without complete structural plans showing how the building is framed, it is difficult to determine if these cracks compromise the integrity of the building. Nonetheless, the crack should be monitored by plant staff in accordance with the previously proposed USACE recommendation. The USACE had recommended that this crack should be monitored by establishing a reference baseline, marking, measuring, dating, and regularly monitoring the crack at 1-meter intervals across the crack.

Another smaller, but sufficiently large-enough vertical crack was also observed by Tetra Tech in the opposite wall section running generally vertically adjacent to and just inside and between the windows and column corner of the existing power house structure**.**

Long-term crack repair considerations will be dependent on how actively the cracks are propagating and/or enlarging, including the cracking mechanism, and verification of the existing structural framing in the area of the column, wall, and header features for each crack. Also, a structural evaluation of the power house building is still recommended.

2) Any rehabilitation and reconstruction will need to consider that this site is subject to high levels of seismic ground motion. To assist in reconstruction efforts, the U.S. Geological Survey (USGS) has developed a preliminary seismic-hazard map of Afghanistan (Fact Sheet 2007-3027). Several sources of seismicity are present in Afghanistan and contribute to appreciable seismic hazard. The Pul-e-Khomri region has a 2 percent chance of ground shaking exceeding 0.5 to 0.6 g in the next 50 years, and a 10 percent chance of shaking exceeding 0.3 g in the next 50 years. The hazard values for Afghanistan are relatively uncertain owing to a lack of information characterizing the sources of seismic hazard, particularly the many faults that might be active.

Tetra Tech concurs.

5.3.3 Standard System-Wide Recommendations (excerpted from April 2008 report)

1) Establish and fund routine maintenance program for each project
2) Identify and establish an inventory of spare parts, equipment, and emergency materials.
3) Perform a system-wide evaluation of hydrologic conditions and subsequent system management program.
4) Collect, duplicate, scan and archive project documents, technical data, and relevant technical information. Maintain set at each project, a set at the Ministry office, and a set in secure archives.

Tetra Tech concurs with the four items noted above.

5.4 Other Tetra Tech Comments

5.4.1 Intake Gates, Trash Rack, and Trash Rake

The existing intake gates and trash rack collect large pieces of debris that are present in the power canal. The debris is then removed by using the trash rake and the material disposed of. This equipment was not inspected during the Tetra Tech site visit, but the plant staff gave no indication of equipment deterioration since the time of the USACE inspection at which time was told by the plant staff that each of these features operated properly.

5.4.2 Penstocks

The steel penstocks that direct flows into the Kaplan turbines were functioning properly, however, the concrete apron supporting the penstocks showed signs of wear and wetness. This was especially noticeable around the existing thrust blocks located against the base of the power house. This damage does not appear to be affecting the functionality of the penstocks, however, further routine inspections are recommended to ensure that this apron concrete remains structurally sound.

5.4.3 Site Foundation Conditions

Tetra Tech performed a general visual inspection of the site foundation conditions at this hydroelectric facility. There was no evidence of ground settlement, depressions, seepage, or slope failure found on site. (No geotechnical investigation or foundation analysis was performed during this Tetra Tech site visit.) As stated for the Pul-e-Khumri I facility, foundation and/or structural design and rehabilitation and reconstruction will need to consider that this plant site is subject to potentially high levels of seismic shaking, and that there is a high level of seismic design uncertainty in the country of Afghanistan, primarily due to existing partial records only of in-country historical seismic events. During the USACE inspection, one of the plant operations crew chief had remembered that a moderate earthquake occurred in the region about 10 years previous had caused a transformer to shut down, however, without any observed structural damage.

6.0 Electrical Condition Summary

The relative benefit of investing in both the Pul-e-Khumri I and II mini-hydro plant facilities should be balanced against simply mothballing the plants and connecting the distribution network to the NEPS system. Tetra Tech's version of the NEPS system diagram indicates a 16-MVA, 220/20-kV substation at Pul-e-Khumri. This station is operational.

At the Pul-e-Khumri II hydro facility, [redacted] was proposed by the USACE to be invested for providing an increase in power from 3.6-MVA to 8.1-MVA. At the Pul-e-Khumri I hydro facility, [redacted] was also proposed to be invested for providing an increase in power from 1.6-MVA to 3.84-MVA. For both plant facilities, [redacted] was proposed to be invested for providing an increase of 6.74-MVA. That's $786/kVA of increased capacity.

On the other hand, for the same [redacted] a second 16-MVA, 220/20-kV transformer could be added at the NEPS substation and a 20-kV line run to the existing mini-hydro substations where it would be transformed to the 6.3-kV already being distributed. The Pul-e-Khumri II transformer would be 10-MVA, 20/6.3-kV and the Pul-e-Khumri I transformer 4-MVA, 20/6.3-kV.

Operational costs for both mini-hydro plants must also be considered. NEPS power at 20-kV should cost $0.06/kWH. Mini-hydro plant maintenance costs, including both plant staff and repair and maintenance consumables should also be considered when computing the operational costs of maintaining these facilities.

In general, maintaining small, isolated generating facilities in an area of a well-established national grid system typically has not proved to be economically feasible in most cases and it may not be the most efficient choice here either.

7.0 Conclusions

7.1 Safety Protection (hand railings and signage) at Pul-e-Khumri I Facility

Safety matters always warrant a first priority no matter the type of project facility. Currently, there is a lack of adequate safety protection, namely hand railings and safety signage, at the tops of concrete walkways on the top of the existing Pul-e-Khumri dams for the protection of plant staff and/or visitors walking along the top walkways of the dam itself, notably above the gate and spillway structures. This lack of safety protection was not addressed by the USACE in its inspection reporting and should comply with the USACE "**SAFETY AND HEALTH REQUIREMENTS MANUAL**" (EM 385-1-1, 2008 or earlier 2005 edition). Therefore, pipe handrails should be installed to at least a minimum height of 0.9 meter (0.9 m) at all locations where needed and to match up with the existing handrails.

7.2 Dredging the Existing Power Canal

As one of the top priorities, the existing sediment in the power canal should be dredged and disposed of at the designated dredge site as discussed above. The selected dump site reportedly is located in the Kar Kar area (the grid for the general dump area is 42SVE7684) approximately 20 t o 25 km away from the City of Pul-e-Khumri in the east-northeast direction. Based on the reported dimensions, the existing carrying capacity of the existing power canal system is on the order of 39 m^3/s, which is roughly 70 percent less than the total carrying capacity of the canal system of 144 m^3/s without the deposited sediment. The USACE previously estimated (in April 2008) that 300,000 $m^3$of sediment was present in the canal, however, the sediment accumulation may be slightly greater now (i.e., on the order of 6 to 7 percent greater because of the interim 2-year period). The much reduced flow conveyance capacity in the existing power canal overall reduces the available flows and net head for producing power at the Pul-e-Khumri II facility. The projected volume of sediment to be removed should be increased for project bidding purposes.

Dredging the canal of the sediments (upwards of the USACE estimated 300,000 m^3) will be the best and only solution to achieve the former total carrying capacity of the canal as needed for restoring the original power generating capacity to the existing Pul-e-Khumri II hydro dam facility. However, as noted in the USACE report, unexploded ordnance (UXO) presents a real safety hazard for performing dredging activities in the power canal. Adequate safety procedures for detecting and disposing with any discovered UXO within and/or along the canal must be developed well in advance of any future dredging work to be performed.

7.3 Spare Parts Ordering and Inventory

Upon delivery of any new equipment and/or spare parts to either the Pul-e-Khumri I or II hydro plants, plant staff at either facility should perform a comprehensive check of the materials received versus the list of equipment and/or spare parts provided by the manufacturer(s) and/or supplier(s). Also, certain specialty tools may be required due to having a given piece of equipment readied for installation. This action needs to be done in order to preclude an observed shortage of a key piece of equipment or specific material at some later installation date that could potentially result in a contractor's or plant staff's downtime.

7.4 Periodic Maintenance of Major Hydroelectric Equipment

The periodic maintenance of major hydroelectric equipment typically requires an outside contractor(s) with special equipment and skill sets and is recommended from hereon for both the Pul-e-Khumri I and II hydroplants. This way, correct maintenance procedures can be maintained and correct parts ordered if required for the maintenance and/or repair of equipment as needed. Plant labor forces can still be used for maintaining the existing minor equipment and tools as has been performed over the years.

7.5 Proposed New Reinforced Concrete Rehabilitation and/or Reconstruction

Due to the importance and critical nature of the USACE proposed reinforced concrete work at both the Pul-e-Khumri I and II hydroelectric power plant facilities, particularly for the existing spillway works at the Pul-e-Khumri I hydroelectric dam, it will be necessary to have effective QA/QC programs. It is unknown if the USACE will provide a Construction Quality Control Manager (CQCM) for the Pul-e-Khumri Project. Also, a field materials testing laboratory should be set up at each hydro plant site under construction and have an independent full-time QA inspector working on site as well. Continuous materials testing will be necessary to ensure that the proper quality control for the separate concrete materials and mixture proportioning including the necessary formwork and steel rebar inspections.

It is presently unknown if the existing spillway concrete at the Pul-e-Khumri I hydroelectric dam is structurally strong enough to support the dynamic forces imposed on it by future hydraulic action of overtopping flow and the dynamic loading conditions imposed on it. At a minimum and for confirmation testing purposes during periods of no flow through the spillway gates, a preliminary assessment of the existing spillway concrete strength of the ogee, apron, and training/sidewall concrete should be tested using a Schmidt Hammer. These test results should provide a basis for an engineering evaluation of the structural integrity of the existing concrete. If entirely new reinforced concrete spillway sections and/or appurtenant structures are to be built, then cofferdam construction above and below each spillway bay may be necessary as well.

A mobile concrete batch plant should be used for performing the necessary concrete work at each plant site. For delivering concrete from the mobile batch plant to the pour site will require either a bucket (to be used with a crane) and/or a set of concrete chutes.
The recommended preferred time period for this work would be during the normal low-flow season on the Baghlan River, which should be during the months of June through October. Also, in order to perform the necessary spillway and associated stilling basin repairs, cofferdams are recommended for construction above and/or below each spillway and/or stilling basin structure in order to perform ready repairs “in the dry” as needed. Dewatering of the spillway structure foundation within each cofferdam enclosure will also be required to the best extent practical. Spillway repairs should be conducted at a single spillway structure, one at a time. (Also, each cofferdam structure(s) will need to be designed accordingly.)

7.6 Baghlan River Left-bank Side and Right-bank Side Downstream Training Wall Replacements

As indicated in the USACE April 2008 report and observed by Tetra Tech, the left-bank downstream training wall is in a state of disrepair and collapse. Evaluating the full extent of needed repairs will require additional site-specific field work and design analysis including surveying, a local geotechnical investigation, and structural engineering designs for constructing new river bank protection improvements. At a minimum, a limited geotechnical investigation and ground survey would be required to prepare a remediation design for stabilizing the existing ground foundation condition and preparing a suitable subgrade foundation for a new reinforced concrete continuous floodwall structure to replace the damaged wall sections. Similarly, new reinforced concrete wall sections are recommended along the right-bank side to be designed and constructed for effectively channeling river flows at this side of the river to protect against future erosion as well. It is also recommended that reconstructing and/or rebuilding the stilling basin blocks in their former locations, particularly at the Spill Gate 4 location, would serve to dissipate the energy from the gate flows, and in particular, reduce the potential of erodible flood-prone river flows, including eddy currents, at the left-bank side of the river thus reducing the chances for further damage to the left bank-side training walls and supporting foundations.

When performing ground stabilization and new reinforced concrete construction work along either the left- or right-bank sides of the Baghlan River, local cofferdam construction and site dewatering is recommended as well.

7.7 Warranty Considerations

It is believed that no company under contract for the rehabilitation construction or reconstruction of certain reinforced concrete structural appurtenances such as the spillway facilities and appurtenances will warranty the work due to the age of the original dam and spillway concrete. Any new concrete placement must be securely dowelled into place with the old concrete. This is a must situation and very good reason for having an effective QC/QA plan. At the end of the reinforced concrete reconstruction at each hydro plant facility, USAI D should require some single entity, either a construction company representative and/or supervisory engineer, to sign off on the rehabilitation/reconstruction design plans (if prepared by others) and/or the follow-up project construction if other than the USACE or actual designer(s) is involved in the project construction quality control.

7.8 Perform a Firm Yield Study of the Baghlan River Flow Regime

The Pul-e-Khumri I and II plant personnel could not produce hydrologic records (river flow or flow-duration data for the Baghlan River nor flow information for the power canal. Rather, only records of the power generated (in Megawatts) by the Pul-e-Khumri I hydro plant operations were produced. It is strongly recommended that a system-wide firm yield hydrologic study should be performed for the historical flow conditions on the Baghlan River at or near the City of Pul-e-Khumri, assuming some lengthy historical record of gaged Baghlan River flows exist or a synthetically-derived flow record developed through runoff correlation techniques/studies. To properly evaluate the available gross head accurately at each plant site, the site-specific headwater and tailwater levels should be measured by the individual plant staff for the full range of Baghlan River flows and the fluctuation in the power canal flows as well.

The end result of the firm yield study should be the development of a flow-duration curve (or curves) for the Baghlan River to be used for each plant site (refer also to next paragraph). The results of this analysis can be used by both Pul-e-Khumri I and II plant personnel for planning ahead and providing optimum management of both the Pul-e-Khumri I and II existing hydro plant system operations as well as when comparing future water demand rates and electrical usage against projected Baghlan River flows, including the seasonal flow variation, to overall better the overall hydro plant system management. Also, the staff gage located on one wall structure at the Pul-e-Khumri II plant facility should be routinely monitored for water level reporting purposes.

7.9 Perform Energy Calculations

Should a Baghlan River firm yield analysis be performed as recommended and presented above, further calculations are recommended to be performed or updated for each facility. The calculations should include those on turbine efficiencies and plant capacities, for power-duration curves, and those on the renewable energy available, renewable energy delivered (i.e. central grid), and renewable energy delivered (i.e., isolated grid and off-grid). The calculations for the renewable energy delivered for the isolated and off-grid sites are also a function of load-duration curve calculations. Manufacturer-reported efficiency data for new turbines that might be installed at either hydro plant can be used in the calculations. Completing the new overall energy calculations should serve as new benchmarks for describing each of the hydropower facility operations as well as their combined plant operations. These calculations should be performed by an outside hydropower specialist and used in conjunction with the Section 6 reporting.

Appendix

Selected Tetra Tech Project Inspection Photographs

Note Heavily-eroded Concrete at Ogee Crest and Along Bottom of Sidewall, Non-uniform and Uneven Spillway Flow Releases, No Safety Hand Railing at Top of Concrete Wall (no safety hand railing at either spillway sidewall), and Deteriorated Wood Planking on Walkway at Pul-e-Khumri I Hydroelectric Dam.

Another View of Heavily-eroded Concrete Along Bottom of Sidewall at Pul-e-Khumri I Hydroelectric Dam. Take Note of Hydraulic Jump Flow Pattern on Sidewall.

View Indicates Deteriorated Wood Planking on Walkway and No Safety Handrail at Left Side of Walkway at Pul-e-Khumri I Hydroelectric Dam (top of ogee spillway is below walkway and is hidden from view).

An Example of a Leaky Gate on Ogee Crest of Spillway at Pul-e-Khumri I Hydroelectric Dam. Also Note Horizontal Crack in Top Concrete Section.

Severely-eroded Turbine Runner Blades from Effects of Cavitation at Pul-e-Khumri I Hydroelectric Power Plant Facility (note evidence of welded steel plate repair work).

View Shows Existing Damaged Stilling Basin Blocks at End of Stilling Basins Below Each Ogee Spillway, Except for Spill Gate 3. Several Stilling Basin Blocks and Sections Presumed as Damaged, Removed and Carried Downstream During High Flood Runoff Events on Baghlan River. Also Take Note of Wide Separation Distance of Concrete Wingwall Sections at Left-bank side of River Channel at Immediate Downstream Side of Bridge Adjacent to Pul-e-Khumri I Hydroelectric Power Plant Facility.

View Indicates the Existing Damage to Concrete Wall Sections Along Left-bank Side of Baghlan River Immediately Downstream of Bridge Adjacent to Pul-e-Khumri I Hydroelectric Power Plant Facility.

View Indicates the Existing Damage to Concrete Wall Sections Further Along Left-bank Side of Baghlan River Downstream of Bridge Adjacent to Pul-e-Khumri I Hydroelectric Power Plant Facility.

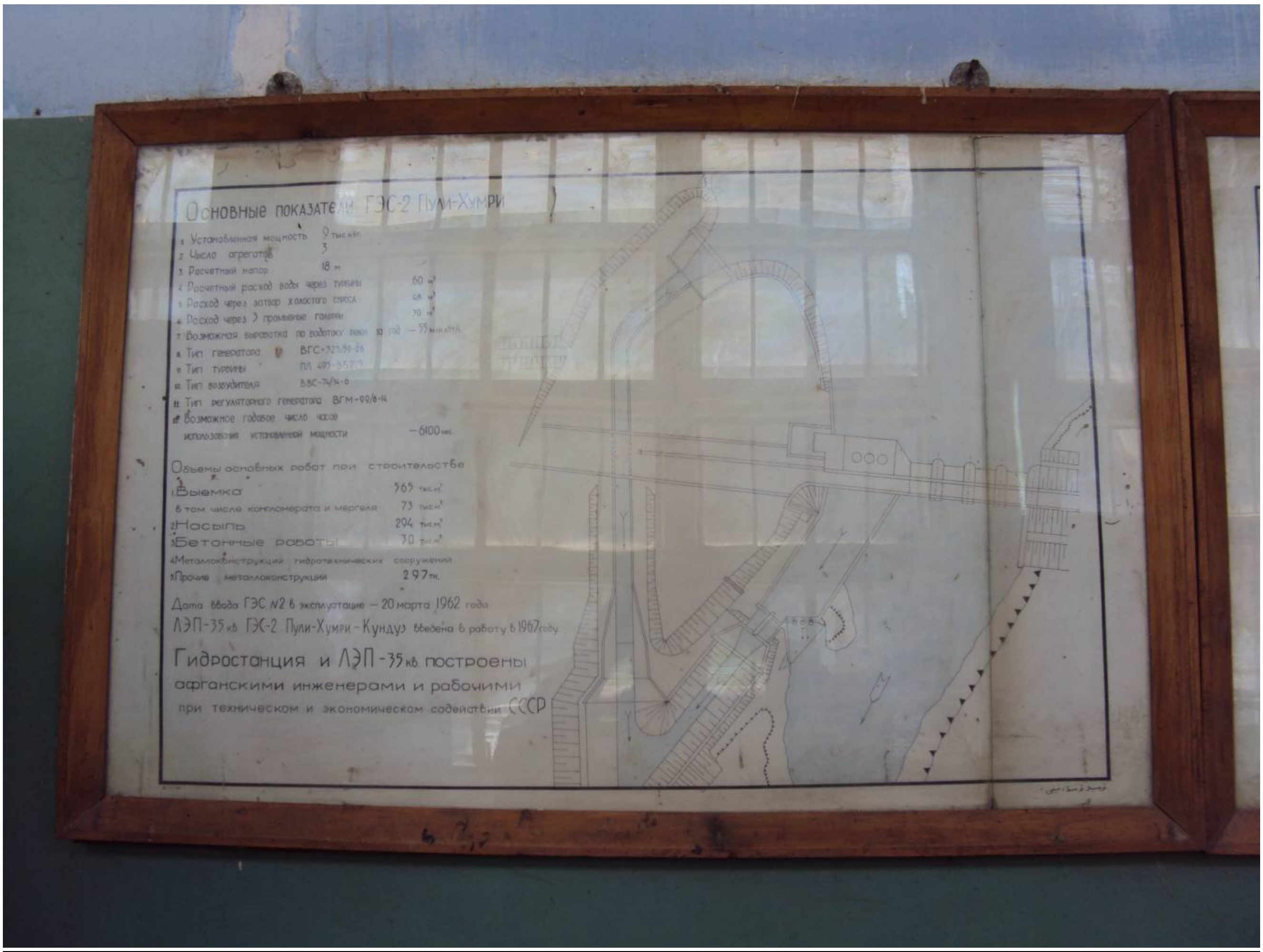
View Indicates the Damage to Existing Low Concrete Wall Sections Along Right-bank Side of Baghlan River Downstream of Pul-e-Khumri I Hydroelectric Dam Facility.

View Indicates the Wall Damage from Leaky Roof in Pul-e-Khumri I Power House Building.

View Showing the Debris that was Trapped and Collected as a Result of a Storm Runoff Event that Occurred the Night Before on the Baghlan River at the Pul-e-Khumri Hydroelectric Power Plant Facility. The Existing Trash Rack/Trash Rake Systems Worked Well.

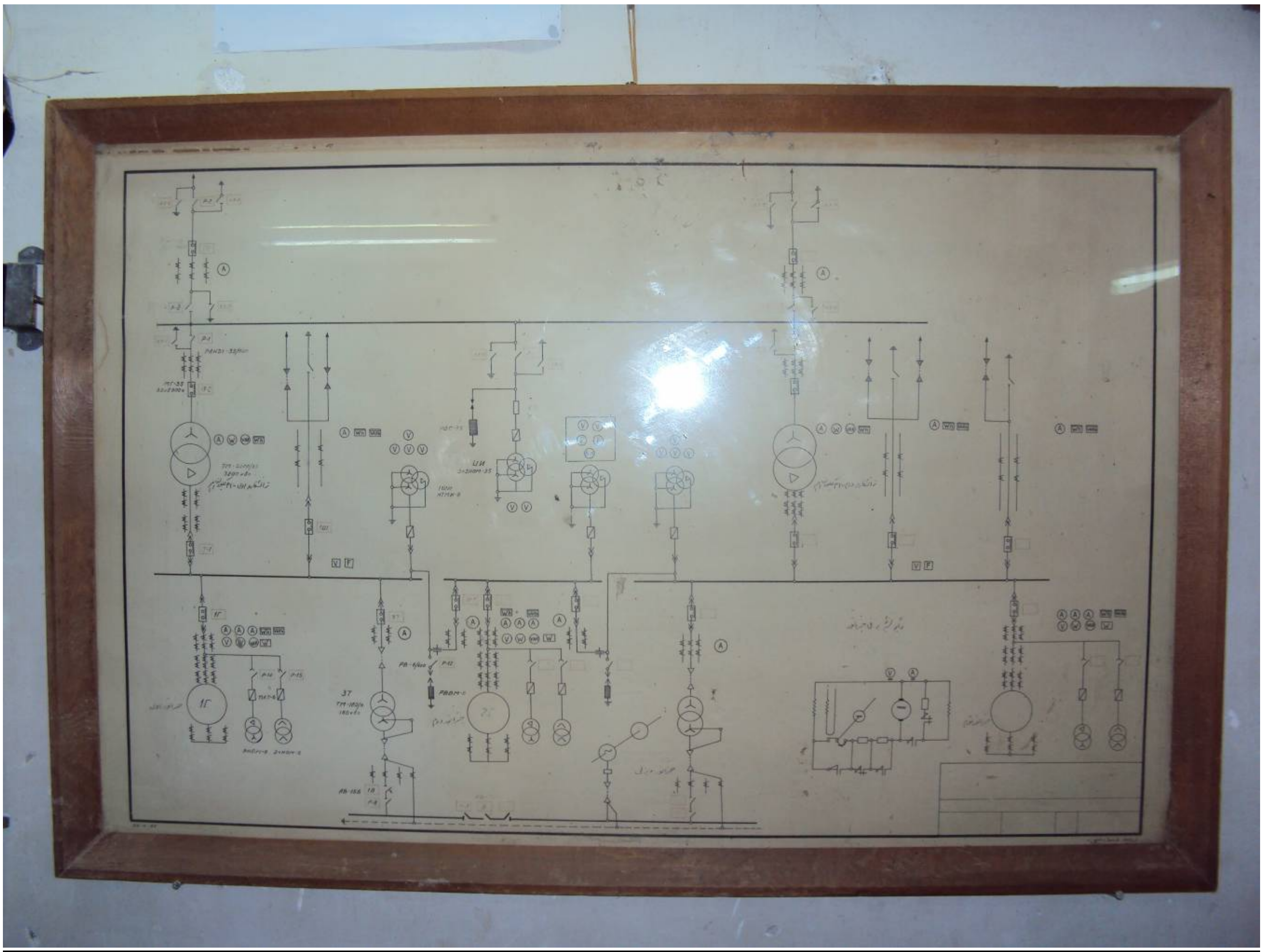
Trash Rake Screen Assemblies at Pul-e-Khumri I Hydroelectric Power Plant Facility (before the Baghlan River storm runoff event occurred).

Existing Sediment-laden Power Canal and Small Pipelines Crossing (reportedly two (2) meters of sediment depth needs to be dredged/removed along approximately six (6) kilometers of canal and disposed of at proposed off-site dump area located near Kar Kar, east of the City of Pul-e-Khumri (see text for discussion on recommended canal dredging activities)).



Russian Schematic Drawing of Pul-e-Khumri II Hydroelectric Dam Facility (upstream side of dam is shown at top of drawing).

Russian Penstock Profile Schematic Drawing at Pul-e-Khumri II Hydroelectric Dam Facility.



Electrical Line Diagram at Pul-e-Khumri II Hydroelectric Dam Facility.

Large Vertical Crack in Wall Running Generally Vertically Adjacent to and Just Inside and Between the Main Entrance and Column Corner of the Existing Power House Structure at the Pul-e-Khumri II Power House. Additional Cracks are Scattered at Various Locations on the Power House Walls. A Long-term Crack Repair Consideration will be Dependent on How Actively the Crack is Propagating and/or Enlarging, Including the Cracking Mechanism, and Verification of the Existing Structural Framing in the Area of the Column, Wall, and Header Features.

A Second Large Vertical Crack in Opposite Wall Section Running Generally Vertically Adjacent to and Just Inside and Between the Windows and Column Corner of the Existing Power House Structure at the Pul-e-Khumri II Power House. A Long-term Crack Repair Consideration will be Dependent on how Actively the Crack is Propagating and/or Enlarging, Including the Cracking Mechanism, and Verification of the Existing Structural Framing in the Area of the Column, Wall, and Header Features. Additional Cracks are Scattered at Various Locations on the Power House Walls.

Staff Gage Affixed to Concrete Wall for Measuring Water Levels at Pul-e-Khumri II Hydroelectric Power Plant Facility (note high water level marks on concrete).

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